INSTITUTIONAL RACISM AND HEALTH: AN ECOLOGICAL ANALYSIS OF MORTGAGE DISCRIMINATION AND SEXUALLY TRANSMITTED INFECTIONS IN BALTIMORE, MARYLAND

by
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Abstract

Racial and ethnic health inequities are widespread in sexually transmitted infections (STIs), including HIV and gonorrhea (GC). Research indicates that anti-Black mortgage loan discrimination, a form of institutional racism, maintains residential segregation and is associated with health inequities. While there is a significant body of research examining social determinants of STIs, no studies have examined the specific relationship between racial mortgage discrimination and STIs. The aim of this study was to examine the association between anti-Black mortgage discrimination and two outcomes, reported cases of GC and separately, HIV per census tract in one Mid-Atlantic city. Anti-Black mortgage discrimination was defined as the odds ratio of mortgage loan denial for Black versus white applicants, controlled for loan amount, income, and gender. Sources of information included the 2012-2017 American Community Survey, 2016-2018 Home Mortgage Disclosure Act, and 2016-2018 public health surveillance data from Baltimore City (N=196 census tracts GC, N=196 census tracts for HIV). Zero-inflated negative binomial regression and geospatial analysis were conducted. For every one unit increase in anti-Black mortgage discrimination, there was a significant decrease, 17% (95%CI: 7%, 26%) in GC cases per census tract. There was not a significant association between mortgage discrimination and HIV cases per census tract. These findings suggest that mortgage loan discrimination may impact STI inequities. Higher anti-Black mortgage discrimination may operate to keep Black people out of neighborhoods with low STI risk and isolate them in neighborhoods with higher ecological STI risk. Interventions should consider economic assets (mortgages) to be a crucial determinant of health outcomes and enact reparations to restore home equity to Black Americans, which will promote health equity.

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Introduction

Racism-Related Health Disparities & Residential Segregation

Social factors are considered "fundamental causes" of racial health inequities (Link & Phelan, 1995). While there is a growing focus on the influence of social factors—or social determinants—on health, there has been limited research on the root causes of racial health disparities (Bailey et al., 2017). Rather, most research conceptualizes race as a biological construct capturing inherent differences instead of a social construct reflecting the effects of racism (Jones, 2000; Hammonds & Herzig, 2008). One form of pernicious and persistent racism is institutional racism, defined by Jones as the differential access to resources, opportunities, and power on the basis of race resulting from institutional practices, customs, and policies (Jones, 2000).

Institutional racism includes discriminatory housing policies that have resulted in residential segregation (Osypuk & Acevedo-Garcia, 2010). Residential segregation, defined as the geographic separation of racial and ethnic groups and disinvestment in communities of color, is a form of institutional racism and a "fundamental cause" of health inequities. In fact, segregation is one of the primary driving factors for Black-White health inequities (Williams & Collins, 2001). Segregation has been shown to impact a wide range of health outcomes, including mortality, general health, access to healthcare, adverse birth outcomes, cancer diagnoses, risk of cardiovascular disease, substance use, and sexually transmitted infections (STIs) and HIV (Williams & Collins, 2001; Gaskin et al., 2009; Gaskin et al., 2012; Yang et al., 2016; Mehra et al., 2017; Landrine et al., 2017; Lutfi et al., 2017). Segregation is hypothesized to affect health via decreased neighborhood quality, housing quality, income and home equity, and access to health resources and care; increased availability of substances, increased rates

of crime and violence, and higher chronic stress (Williams & Collins, 2001; Forrester et al., 2019) (See Figure 1).

STI Disparities

Within infectious diseases, racial health disparities are severe in STIs (Jennings et al., 2005; Eggleston et al., 2011; Biello, 2013; Pugsley et al., 2013; Buot et al., 2014; Stenger et al., 2014; Fennie et al., 2015; Henderson, 2016; Lutfi et al., 2017, Ibragimov et al., 2018; Noah et al., 2018). For example, in 2018 the national rate of reported gonorrhea cases among Blacks was 7.7 times the rate among Whites and the rate of HIV diagnosis among Blacks was 8.5 times the rate among Whites (CDC, 2018; Kaiser Family Foundation, 2020).

Acevedo-Garcia's conceptual framework posits that residential segregation impacts infectious disease transmission by leading to an “epidemiological injustice” wherein STIs including HIV are highly concentrated within certain racial/ethnic populations located in areas of high ecological risk (Acevedo-Garcia, 2000). Segregation may lead to inequities in STIs/HIV specifically through its impacts on sexual and social networks, access to healthcare, and environments conducive to high-risk behaviors (Biello, 2013). Segregation is associated with detrimental HIV outcomes for Black patients, the results for other racial/ethnic groups are less clear (Fennie et al. 2015; Henderson, 2016; Ibragimov et al. 2018). Studies of segregation and gonorrhea have generally found a detrimental effect on health, with some variation by the specific segregation index or income level (Thomas & Gaffield, 2003; Biello, 2013; Pugsley et al. 2013; Lutfi et al., 2017; Ibragimov et al., 2018; Noah et al., 2018).

Residential Redlining, Mortgage Discrimination, & Health Disparities

Residential redlining is a likely enforcer of segregation and therefore may increase the risk of STI transmission (Acevedo-Garcia, 2000). Residential redlining was a federal system for mapping neighborhoods by financial risk for mortgage lending, with racial composition used as a

determinant of risk. Starting in 1934, the Home Owners' Loan Corporation (HOLC) mapped 239 U.S. cities, including New York, Philadelphia, and Baltimore. These maps ranked neighborhoods by credit risk from "Best," "Still Desirable," "Definitely Declining," to "Hazardous." "Hazardous" neighborhoods were color-coded red, hence the name "redlining," and were defined by the presence of any residents of color (Nelson et al.; Federal Housing Administration, 1938). The Federal Housing Administration (FHA) denied insurance for any mortgage loan within these "hazardous" neighborhoods. Additionally, individual applicants of color were and still are more likely to be denied insurance or targeted for high-risk, high-cost loans compared to White applicants (Cheng et al., 2015; Rugh et al., 2015; Massey et al., 2016). Thus, HOLC redlining maps were by their very definition a mechanism used to racially discriminate and make racism an institutional practice in the mortgage lending industry.

The impact of redlining and mortgage discrimination is substantially debilitating. Homeownership is the principal driver of household wealth and mechanism for building intergenerational wealth, so many Black families were unable to accumulate wealth in the form of home equity over generations (Nelson et al.; Pickett & Pearl, 2001; Williams & Collins, 2001; Pew Research Center, 2011; Massey et al., 2016). Additionally, redlining and mortgage discrimination reinforced residential segregation. Lack of resources and privilege in Black neighborhoods creates and perpetuates optimal individual and ecological conditions for adverse health outcomes such as STIs (Figure 1).

Several studies examine the impact of historical redlining on health outcomes or health-related neighborhood characteristics. All of these studies have found associations between historical redlining and modern-day health disparities, although only one investigated an infectious disease (Huggins, 2017; Jacoby et al., 2018; McClure et al., 2019; Krieger et al., 2020a; Krieger et al., 2020b; Trangenstein et al., 2020). The infectious disease study was an observational cartographic analysis of 1952 tuberculosis (TB) cases and their relationship to the 1934 HOLC map in Austin, Texas. The findings suggested an association between historical TB

cases and redlining, whereby TB cases were up to 20 times higher in redlined than in non-redlined areas (Huggins, 2017). There has also been one study in the current city of interest. A study of 2016 alcohol retail outlets in Baltimore, MD found that redlining was associated with greater clustering of outlets (Trangenstein et al, 2020). Yet no studies of redlining to date have investigated modern day STI/HIV outcomes.

Several studies have used an index of mortgage discrimination, calculated from Home Mortgage Disclosure Act data, as a proxy for the modern effects of historical redlining. The mortgage discrimination index captures the odds of mortgage loan denial for individual Black versus White applicants. While no studies have examined the effect of mortgage discrimination on STI/HIV outcomes, a growing body of research has focused on the impact of mortgage discrimination on other health outcomes such as pregnancy, cancer survival, and general health (Gee, 2002; Mendez et al. 2011; Mendez et al., 2013a; Mendez et al., 2013b; Beyer et al, 2016; Zhou et al., 2017; Matoba et al, 2019). Notably, a recent study examined the impact of county-level mortgage discrimination on racial/ethnic sexual homophily—partners sharing the same race/ethnicity—in 19 US cities (Linton et al., 2020). Living in a county with higher mortgage discrimination against Black people who inject drugs (PWID) was associated with higher odds of homophily for PWID of Black and white race. Given that homophily is associated with certain racial and ethnic disparities in HIV infection, the effect of mortgage discrimination on racial/ethnic HIV outcomes warrants further study.

Study objective

This study aims to examine the association between an index of mortgage discrimination and case counts of GC and HIV (separately) at the census tract level in Baltimore, Maryland from 2016-2018.

We chose the outcome because racial inequities in STIs are among the greatest and most persistent disparities of all health outcomes (Thomas & Gaffield, 2003; Jennings et al.,

2010; Biello, 2013; Pugsley et al., 2013; Fennie et al., 2015; Henderson, 2016; Lutfi et al., 2017; Ibragimov et al., 2018; Noah et al., 2018). Figure 1 links current mortgage discrimination practices to STIs. Institutional racism—first through redlining and then through mortgage discrimination—led to disinvestment in redlined neighborhoods and investment in non-redlined neighborhoods. These inequities affected access to neighborhood-level factors that influence STI risk. As a result of mortgage discrimination, segregation is enforced; Black residents are more likely to be kept out of low STI risk neighborhoods and confined to high-risk neighborhoods, while White residents are more likely to reside in those low STI risk neighborhoods. Mortgage discrimination may influence case counts of GC and, separately, HIV through neighborhood ecological risk and STI prevalence in available sex partners.

Mortgage discrimination is operationalized as an index which measures the odds of mortgage loan denial for Black versus White applicants, adjusted for loan amount, applicant income, and applicant sex. While mortgage discrimination is targeted at Black and Latinx loan applicants, this study focuses on the impact on Black applicants because Baltimore is a majority-Black city (United States Census, 2010). The index of mortgage discrimination popularized by Mendez has been validated in many studies of various health outcomes (Gee, 2002; Mendez et al., 2011; Mendez et al., 2013a; Mendez et al., 2013b; Beyer et al., 2016; Zhou et al., 2017; Matoba et al., 2019) In census tracts with a higher index of mortgage discrimination, Black applicants are more likely to be denied a loan (experience greater mortgage loan discrimination) than White applicants, comparable across income, loan amount, and sex. The index is considered a marker of the extent of a census tract's racially discriminatory norms or values. Therefore, the odds of mortgage discrimination are likely higher in White neighborhoods (where Black applicants are denied loans), which are more likely to be high income and have lower ecological risk for STIs due to institutional racism. Mortgage discrimination confines Black applicants to Black neighborhoods, which are more likely to be low-income and have higher ecological risk for STIs. Neighborhood racial composition can be

seen as not a determinant of STI rates, but as a marker for the extent of institutional racism in housing (Figure 1).

Hypothesis

Mortgage discrimination operates to keep Black homeowners out of neighborhoods where they are not desired--White neighborhoods with lower ecological risk for STIs. The hypothesis is that higher census-tract level mortgage discrimination against Black applicants, specifically the index utilized in this study, is thus associated with lower GC and separately, HIV case counts per census tract.

Methods

Overview

The study design is an ecological analysis of the relationship between residential mortgage discrimination (2016-2018) and HIV and gonorrhea case counts (2012-2017) at the census tract (CT) level.

Setting

Baltimore is well-suited to a study of mortgage discrimination and STI/HIV disparities. Black experience significantly elevated rates of multiple STI/HIV outcomes than White residents do (Jennings et al., 2005; Jennings et al., 2010; Eggleston et al., 2011). The rate of gonorrhea infection in Maryland in 2018 was 7.6 times higher in Black than in White residents. Furthermore, 82.7% of people living with HIV/AIDS in 2017 were Black compared to 8% who were white (Maryland Department of Health, 2018). Additionally, Baltimore is classified as hypersegregated (Massey & Tannen, 2015). In fact, it was the first U.S. city to mandate

segregation of Black and White residents. Proponents of a 1910 segregation law believed that "Blacks should be quarantined in isolated slums in order to reduce the incidence of civil disturbance, to prevent the spread of communicable disease into the nearby White neighborhoods, and to protect property values among the White majority" (Power, 1983). This suggests a strong legacy of institutional racism. In Baltimore, Black people are the predominant racial group (62.8% of the city's population) and are deeply impacted by these racist policies (United States Census, 2020).

Data Sources

This study included routinely collected public health surveillance data on gonorrhea and HIV from the Baltimore City Health Department (BCHD), mortgage application data from the Home Mortgage Disclosure Act (HMDA), demographic data from the American Community Survey (ACS), and historical geographic redlining data from Mapping Inequality.

The routinely collected public health data includes reported cases of gonorrhea and HIV. Public health surveillance data on all reports of gonorrhea (all anatomical sites) from January 1, 2014 to December 31, 2016, were obtained from the BCHD. Data were collected through routine disease reporting and control, including STD Surveillance Network-enhanced surveillance interviews for a random sample of gonorrhea cases (Tilchin et al., 2019). HIV public health surveillance data from January 2014 to December 2016 were obtained from the BCHD. GC and HIV positive individuals with complete residential addresses were geocoded to a census tract within Baltimore City. A new HIV diagnosis was defined as a diagnosis during the study time period for an individual without a previously recorded history of a positive HIV test (Leifheit). A GC diagnosis was defined as any diagnosis, whether first or repeat, reported during the study period (Tilchin et al., 2019).

The HMDA is an administrative database created by the Federal Reserve Board that collects yearly information from banks and other lending institutions providing mortgage loans.

The database collects mortgage loan information from lending institutions across the United States and reports information about loan type and amount, disposition, and applicant characteristics (Mendez et al., 2011). The American Community Survey (ACS) is an ongoing annual survey by the Census Bureau that collects social and economic characteristics for small geographic areas, matched to Census annual population estimates. (United States Census, 2019).

Mapping Inequality is a collaboration among the University of Richmond, Virginia Tech, University of Maryland, and Johns Hopkins. The project digitized the Home Owners' Loan Corporation maps and area descriptions from 1935-1940 and created geographic information software files of the HOLC maps for many U.S. cities (Nelson et al.).

The study used HMDA data from 2016-2018 that were aggregated to the census tract (CT) level and characterized the result (acceptance/denial) of individual mortgage loan applications. Five-year ACS data from 2013-2017 at the census tract were used and included education, age, sex, and population counts. STI surveillance data from Baltimore City Health Department included diagnoses of HIV and gonorrhea from 2016-2018, which were pooled at the census tract level for this study. Finally, geographic information software (ArcGIS) files of Baltimore's 1937 HOLC redlining maps were obtained from Mapping Inequality. Data from the Baltimore City Health Department were linked with data from the HMDA and ACS by census tract.

Measures

Primary outcome

The outcome was separate counts of HIV and GC diagnoses per census tract. Census-tract level case counts of HIV and GC were modeled separately; while both have significant Black-White disparities in incidence, they have distinct epidemiologies and spatial distributions. Gonorrhea incidence is over 15 times higher than HIV incidence in the US; in

2018, 583,405 cases of gonorrhea were diagnosed compared to 37,968 HIV cases (Centers for Disease Control and Prevention, 2018; Centers for Disease Control and Prevention, 2020). Disparities exist among key populations; among sex workers, the prevalence of GC is over twice as high (12.6%) as that of HIV (5%) in Baltimore City (Lim et al., 2019; Park et al., 2019). Among people who inject drugs, HIV prevalence is more than twice as high (8.7%) as GC prevalence (3.3%) (Plitt et al., 2005; Degenhardt et al., 2017).

Primary exposure

The exposure of this study was mortgage discrimination at the census tract level, measured continuously. This was captured through the mortgage discrimination index developed by Mendez et al, which quantifies the odds of mortgage loan denial for Black compared to White applicants, adjusted for loan amount, income, and sex (Mendez et al., 2011). In census tracts with a higher index of mortgage discrimination, Black applicants are more likely to be denied a loan than White applicants, comparable across income, loan amount, and sex.

Data from HMDA were used to construct mortgage discrimination indices for each census tract in Baltimore for years 2016-2018. Per the methods used by Mendez et al, the index excluded applications that were incomplete, loans that were purchased by financial institutions, non owner-occupied residences, loans for home improvement, and multifamily units (Mendez et al., 2011). Census tracts were excluded if they had fewer than two applications (Matoba et al., 2019). In contrast to data from years 2016 and 2017, the 2018 HMDA data did not include the variable owner occupancy, so data from this year were included and then a measurement analysis was conducted (Federal Financial Institutions Examination Council, 2018) (Table 1). The measurement analysis shows that the mortgage discrimination index for 2018 fell within the range of the indices for 2016-2017. The mortgage discrimination index was calculated according

to the equation developed by Mendez et al. (2011), where *i* is an index for individuals within census tracts and *j* is an index for census tracts:

Level 1 equation:

$$L_n\left[\frac{p_{ij}}{1-p_{ij}}\right] = \beta_{0j} + \beta_{1j}(race\ of\ applicant)_{ij} + \beta_{2j}$$
$$(gross\ annual\ income)_{ij} + \beta_{3j}$$
$$(loan\ amount)_{ij} + \beta_{4j}(sex\ of\ applicant)_{ij}$$

Level 2 equation:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$
$$\beta_{1j} = \gamma_{10} + u_{1j}$$
$$\beta_{pj} = \gamma_{p0} + u_{pj}(for\ p > 1)$$
$$\begin{bmatrix} u_{0j} \\ u_{1j} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \tau_{00} \\ \tau_{10}\tau_{11} \end{bmatrix}\right)$$

The outcome is the natural log odds of being denied a loan where u_{0j} is the random effect for census tract *j*. One assumes that the random effects for the intercept and slope were normally distributed with means of zero, variance of $\tau 00$for the intercept and $\tau 11$ for the slope, and a covariance between the intercept and slope of $\tau 10$ (Mendez et al., 2011). The multilevel model allows incorporation of both individual- and census tract-level information to capture both individual- and census tract-level mortgage discrimination.

The resulting mortgage discrimination index was a continuum of mortgage loan discrimination for each census tract, adjusted for loan amount, income, and applicant gender. For example, a redlining index of 2.0 indicates a census tract where the odds of loan denial for Black applicants are twice the odds of loan denial for white applicants; a score of 1.0 indicates no racial difference in loan denial (Mendez et al., 2013a). Previous studies have categorized the index as indicative of redlining at the point where loan applicants of color were disfavored by 40% compared with White applicants, calculated as an odds ratio (OR) of 1.4 (Gee, 2002; Pickett et al., 2005). Average mortgage discrimination indices for all census tracts in Baltimore were compared across the three-year study time period to see if there were any significant temporal changes (Table 1).

Neighborhood definition

Neighborhoods were defined in this study as census tracts within the county of Baltimore City, Maryland, because these were the smallest neighborhood units that were publicly available in the HMDA database.

Covariates

Covariates at the census tract level included median age, percent female, and percent with less than high school education completed.

Statistical analysis

Statistical analysis was conducted between the exposure, mortgage discrimination, and the two outcomes (counts of HIV and GC) at the census-tract level.

For descriptive statistics, demographic characteristics as well as STI case counts were stratified by quartiles of the mortgage discrimination index (with Q1 being lowest mortgage discrimination and Q4 being highest). Additionally, demographic characteristics and the mortgage discrimination index were stratified by low and high STI case counts. In general, STI research classifies case counts with a mean or median cut-off or classifications such as quartiles or quintiles. Studies commonly utilize the local STI distribution to inform the cut-off to ensure local relevance (Pugsley et al., 2013; Buot et al., 2014). In this study, the median was chosen as the cutoff because the local distributions of gonorrhea and HIV were non-normal. A low GC case count was defined as less than or equal to the median GC count (n=53) across all CTs, and a low HIV case count was defined as less than or equal to the median HIV count (n=3) across all CTs. T-tests were done to compare the distribution of exposure and covariates between low and high GC and HIV case counts. Sensitivity analysis/ model diagnostics was conducted to compare the goodness-of-fit of various regression models (Table 5). Akaike's and

Schwarz's Bayesian information criteria were used to determine which type of regression was the best fit for the data.

Bivariate analysis was conducted with zero-inflated negative binomial regression for the associations between the continuous mortgage discrimination index, demographic factors, and the outcome of high STI counts (above the median case count as defined above).

The adjusted zero-inflated negative binomial regression model for association between mortgage discrimination index and STI counts included median age, percent female, and percentage with less than a high school education as covariates. Younger age and female sex were included as potential confounders based on prior literature of associations with increased STI incidence (Jennings et al., 2010; Eggleston et al., 2011; Buot et al., 2014; Centers for Disease Control and Prevention, 2017). Percentage with less than high school education was chosen because it has been shown to be associated with higher rates of HIV diagnoses (Buot et al., 2014; Henderson 2015; Ibragimov et al., 2018). Each is potentially also associated with the exposure of interest, mortgage discrimination.

All analyses were performed in Stata Version 15.1 and statistical significance was defined as $p<0.05$.

Geospatial analysis

ArcGIS shapefiles of Baltimore's 1937 HOLC maps were downloaded from Mapping Inequality (Nelson et al.). For descriptive analysis, the mortgage discrimination index, case counts of HIV, and case counts of GC were mapped across Baltimore City census tracts. All analysis was performed in ArcGIS Pro Version 2.4.0.

The Institutional Review Board at Johns Hopkins Bloomberg School of Public Health determined the study to be exempt from review of human subjects research.

Results

Across all census tracts, the annual odds of mortgage loan denial were significantly greater for Black versus White applicants from 2016-2018, indicating the presence of widespread mortgage discrimination. The average odds of mortgage discrimination against Black applicants were 3.09 in 2016, 2.89 in 2017, and 2.20 in 2018. The average mortgage discrimination index across all census tracts from 2016-2018 indicated that the odds of loan denial for Black applicants were over 2.5 times as high as the odds of loan denial for White applicants. Additionally, nearly all of the census tracts (191/196) had an average annual mortgage discrimination index of at least 1.4, a threshold that previous studies have considered to be indicative of redlining (Table 1) (Pickett et al, 2005; Gee, 2008).

Table 2 shows STI case counts and demographic covariates stratified by increasing quartiles of mortgage discrimination index. As the mortgage discrimination index increased (from quartile 1, lowest discrimination, to quartile 4, highest discrimination), the average GC case count and HIV case count decreased. Median age, percent female, and percent with less than high school education all decreased with increasing levels of mortgage discrimination.

Figure 2 shows the geographic distribution of the mortgage discrimination index and case counts of HIV and GC in Baltimore City by census tract. Generally, the odds of mortgage loan denial for Black versus White applicants appeared higher in the White high-income areas and lower in the Black low-income neighborhoods. Case counts of both GC and HIV were higher in Black low-income neighborhoods and lower in White high-income neighborhoods.

Table 3 shows that when stratified by high (above median) and low (below/equal to median) GC case counts across all census tracts, the average mortgage discrimination index was significantly lower in high case count tracts (2.367 ± 0.722) compared to low case count tracts (2.824 ± 0.798). On average across all census tracts, high GC case count tracts had statistically significantly greater percentage female, as well as residents with less than a high

school education than did low GC case count tracts. While high GC case count census tracts had a higher median age than low case count census tracts, this relationship was not statistically significant.

Table 4 shows that when stratified by high (above median) and low (below or equal to median) HIV case counts, the average mortgage discrimination index is statistically significantly higher in low HIV case tracts (2.744 ± 0.775) than in high case count tracts (2.418 ± 0.782). On average, high HIV case count census tracts also had statistically significantly more residents with less than a high school education. While such census tracts had a higher percent female and lower median age, these relationships were not statistically significant.

Akaike's and Schwarz's Bayesian information criteria indicated that a zero-inflated negative binomial regression was the best fit for the data for both STIs (Table 5). Unadjusted regression analysis found a statistically significant inverse relationship between mortgage discrimination and GC case counts (Table 6). In a given census tract, increasing mortgage discrimination against Black loan applicants was associated with a 27% decrease in GC case count. Percent female (IRR=21.70, 95% CI: 2.02, 233.32) and percent with less than a high school education (IRR=66.89, 95% CI: 21.40, 209.10) were statistically significantly associated with GC case count, but median age was not (IRR=1.00, 95% CI: 0.99, 1.02). The adjusted model (controlled for median age, percent female, and percent with less than high school education) found a slightly lower statistically significant decrease in GC case count per unit increase in mortgage loan discrimination (IRR=0.83, 95% CI: 0.74, 0.93). In other words, in a given census tract, increasing mortgage discrimination against Black loan applicants was associated with a 17% decrease in GC case count. In this model, median age and percent female population were not statistically significantly associated with GC case count. The relationship between percent less than high school education and GC count remained significant (IRR=37.17, 95% CI: 12.09, 114.25).

Unadjusted regression analysis did not find a statistically significant relationship between mortgage discrimination and HIV case counts (IRR=0.98, 95% CI: 0.87, 1.09). Percent with less than a high school education was statistically significantly associated with higher HIV case counts (IRR=2.97, 95% CI: 1.06, 8.28). Median age and percent female were not significantly associated with HIV case counts. The adjusted model found no statistically significant relationship between mortgage discrimination and HIV case count (IRR=1.02, 95% CI: 0.90, 1.16). A statistically significant relationship was seen, however, between less than high school education and HIV case count (IRR=3.09, 95%CI: 1.05, 9.02). Median age and percent female were not significantly associated with HIV case count.

Discussion

The objective of this study was to analyze the relationship between census-tract level mortgage discrimination and gonorrhea and HIV case counts, separately. Regression analysis indicated that greater census-tract level mortgage discrimination against Black applicants was significantly associated with lower GC case counts (17% lower) but not with HIV case counts (Table 6). The higher odds of mortgage discrimination in a census tract, the higher the White composition and average income. Mortgage discrimination excludes and segregates Black homeowners out of more privileged neighborhoods, confining them to neighborhoods with higher ecological risk of STIs. These results reflect the downstream result of historical redlining, mediated through mortgage loan discrimination: the disproportionate loss of home equity among Black versus White residents and the increased risk of STIs in Black neighborhoods (Figures 1 and 2). The lack of a statistically significant result for HIV may reflect the impact of low HIV case counts per census tract; HIV is much rarer than GC (Centers for Disease Control and Prevention, 2018).

On average across Baltimore census tracts, Black mortgage loan applicants were significantly more likely to be denied a loan than White applicants, controlling for loan amount, applicant sex, and applicant income (Table 1). In fact, the average Black-White mortgage discrimination from 2016-2018 indicated that Black applicants were over 2.5 times (and as high as 4 times) more likely to be denied a mortgage loan. Each of the average annual mortgage discrimination indices as well as the average index across all study years fell above 1.4, a threshold that previous studies have categorized as being indicative of redlining (Pickett et al, 2005; Gee, 2008). Furthermore, 97% of census tracts had a mortgage discrimination index of 1.4 or higher. This indicates a significant pattern of systemic racism against Black mortgage loan applicants in Baltimore. While this is the first study to examine racial mortgage discrimination and health outcomes in Baltimore, previous research provides evidence of mortgage discrimination in the same city. One study found that Black people in Baltimore paid 5-11% more than Whites in monthly mortgage payments to Wells Fargo, putting them at higher risk of foreclosure and causing over $2 million total loss of home equity (Rugh et al., 2015).

The geographic patterns of GC and HIV cases (Figure 2) are consistent with previous studies (Bernstein et al., 2004; Jennings et al., 2005). Research has categorized a characteristic geographic pattern in Baltimore in which adverse health outcomes are clustered in Black lower-income areas and positive health outcomes are concentrated in White higher-income areas (Brown, 2016). The geographic pattern of mortgage discrimination appears to be inversely correlated with STI incidence. Thus, where mortgage discrimination is the lowest (in Black neighborhoods), STIs are the highest, whereas where discrimination is highest (White neighborhoods), STIs are low. Geospatial analysis supports the hypothesized pathways shown in Figure 1. The pattern may be a manifestation of historical redlining, which established mortgage discrimination as an industry standard functions to keep Black people out of neighborhoods with low STI incidence, which tend to be higher income, majority-White.

Descriptive statistics further support the inverse association between census-tract level mortgage discrimination and STI case counts (Tables 3 and 4). Lower HIV and GC case count tracts had more “privileged” sociodemographic factors, while high HIV and GC case count tracts had more “underprivileged” sociodemographic factors. When stratified by quartiles of increasing mortgage discrimination index, a similar pattern was evident (Table 2). These sociodemographic characteristics suggest a lack of economic, social, and health privileges and opportunities for residents of historically redlined, currently underinvested census tracts. Increasing lower-education population is associated with increased GC and HIV counts, and increasing percent female is associated with increased GC case counts. Higher percent female and lower-education populations are just some of the demographics characteristic of historically redlined neighborhoods (Figure 1). Median age does not appear to have a linear relationship with STI case counts, which may be a reflection of a slightly skewed age distribution.

Unadjusted regression further supported the significantly positive associations between percent female and GC case counts, and less than high school education and case counts of GC and HIV. In adjusted regression, only less than high school education was significantly associated with GC and HIV case counts. The associations between these characteristics and STI incidence are consistent with the literature (Jennings et al., 2010; Eggleston 2011; Pugsley et al., 2013; Buot et al., 2014; Henderson et al., 2015; Centers for Disease Control and Prevention, 2018; Ibragimov et al., 2018). The lack of a statistically significant relationship between median age and STIs may be a result of the age distribution. Higher education, median age, and a more equitable ratio of female/male residents generally are associated with more privilege and opportunity for a neighborhood, and may explain their association with lower STI case counts. On the other hand, higher percent female, lower-education, and lower median age are outcomes of systemic oppression (such as institutional racism) that has decreased neighborhood resources, which is associated with higher STI case counts (Figure 1).

Both unadjusted and adjusted regression found an inverse relationship between the mortgage discrimination index and GC case count, but not HIV case count. The lack of a statistically significant association between mortgage discrimination and HIV case count may be a result of low statistical power due to the low HIV case counts. However, the impact of mortgage discrimination on GC case counts is clear. Mortgage discrimination operates to keep Black homeowners out of richer, Whiter neighborhoods where the ecological risk of STIs is lower. Black homeowners are segregated to poorer neighborhoods where the ecological risk of STIs is greater. When Black residents are kept out of high-resource neighborhoods, excluded from privilege, and denied opportunity, the resulting ecological injustice creates ideal conditions for high STI rates (Acevedo-Garcia, 2000). Through the legacy of redlining, the government has isolated Black people in neighborhoods with high poverty, little access to the formal economy, poor healthcare, increased incarceration rates, and other factors that are associated with high prevalence of STIs (Figure 1) (Hogben & Leichliter, 2008; Feaster et al., 2016; Henderson, 2016).

This phenomenon is also known as the “ghettoization of America” and can be traced back to FHA policies that "called unequivocally for the containment of African Americans" in order to establish a stable White middle class after the Great Depression (Kimble, 2007). The FHA manual states: “The infiltration of inharmonious racial groups will... lessen the desirability of residential areas,” making them unstable and lowering housing values (Federal Housing Authority, 1938). More than $120 billion in new mortgages were financed from 1934 to 1962, with less than two percent of the benefit going to Black people (Lipsitz, 2006). Decades of denying home equity to Black loan applicants accomplished the government’s goal: to keep Black people out of White neighborhoods. Today, predatory loan originators still target Black and Latinx residents, especially those already in debt, for high-cost high-risk loans that often result in loss of home equity (Coates, 2014; Steil et al, 2018). In this way, mortgage discrimination has deprived Black Americans of generational wealth for nearly the last century.

This study has several limitations. First, due to the ecological nature of this study, only census-tract level data was analyzed and the effect of individual-level factors are not known. Additionally, there is a possibility of uncontrolled confounding due to other potential confounders in the causal pathway (Figure 1). This study focused only on anti-Black mortgage discrimination because Baltimore is a majority-Black city with a strong legacy of anti-Black racism. However, non-Black people of color also face the debilitating effects of mortgage discrimination (Gee, 2002). The STI data in this study was limited to reported cases of GC and HIV, which is likely an underestimate of the true burden of disease due to asymptomatic cases and underreporting (Jennings et al. 2010; German et al., 2016). Additionally, STI diagnoses were only collected for patients with complete residential addresses, so people experiencing homeless or unstable housing may have been undersampled. Finally, the ACS data was collected from 2012-2017, while the HMDA and STI data was collected from 2016-2018.

A powerful marker of institutional racism, mortgage discrimination is a salient social determinant of health to study because its effects on racial inequity are more proximal than the effects of generalized segregation. For centuries of being targeted by racism, Black Americans are owed systemic change that redistributes wealth to Black individuals and neighborhoods. Possibilities for housing specifically include grants that redistribute home equity to Black applicants and reparative mortgage lending practices (Kaplan et al., 2007; Ray, 2020). Reparations have been endorsed by the NAACP, proposed in Congress, and agreed to in court settlements by major financial institutions (Coates, 2014). Such interventions would ideally allow Black people to participate equitably in homeownership, the primary driver of American household wealth (Pew Research Center, 2011), which would also support reinvestment in Black neighborhoods. Increased resources in underinvested Black neighborhoods would likely decrease poverty, lower substance use, increase employment, improve access to healthcare, and lead to other positive changes that impact well-being. Investment in Black neighborhoods

would lower the individual and ecological risk of STIs in Black communities and promote health equity.

Conclusion

For every one unit increase in the index of mortgage discrimination, there was a significant decrease (95%CI: 7%, 26%) in GC cases per census tract in Baltimore. There was no significant association between mortgage discrimination and HIV cases per census tract. This suggests that anti-Black mortgage loan discrimination, a form of institutional racism, may impact STI inequities. Higher anti-Black mortgage discrimination may operate to keep Black people out of neighborhoods with low ecological STI risk and isolate them in neighborhoods with high ecological STI risk. Public health policymakers should consider wealth in the form of home equity to be a crucial determinant of health inequity. Interventions for mortgage discrimination and STI risk should focus on restoring home equity to Black Americans through reparations.

Tables and Figures

Figure 1. Directed acyclic graph (DAG) of the relationship between race, redlining, mortgage discrimination, segregation, and STI inequities.

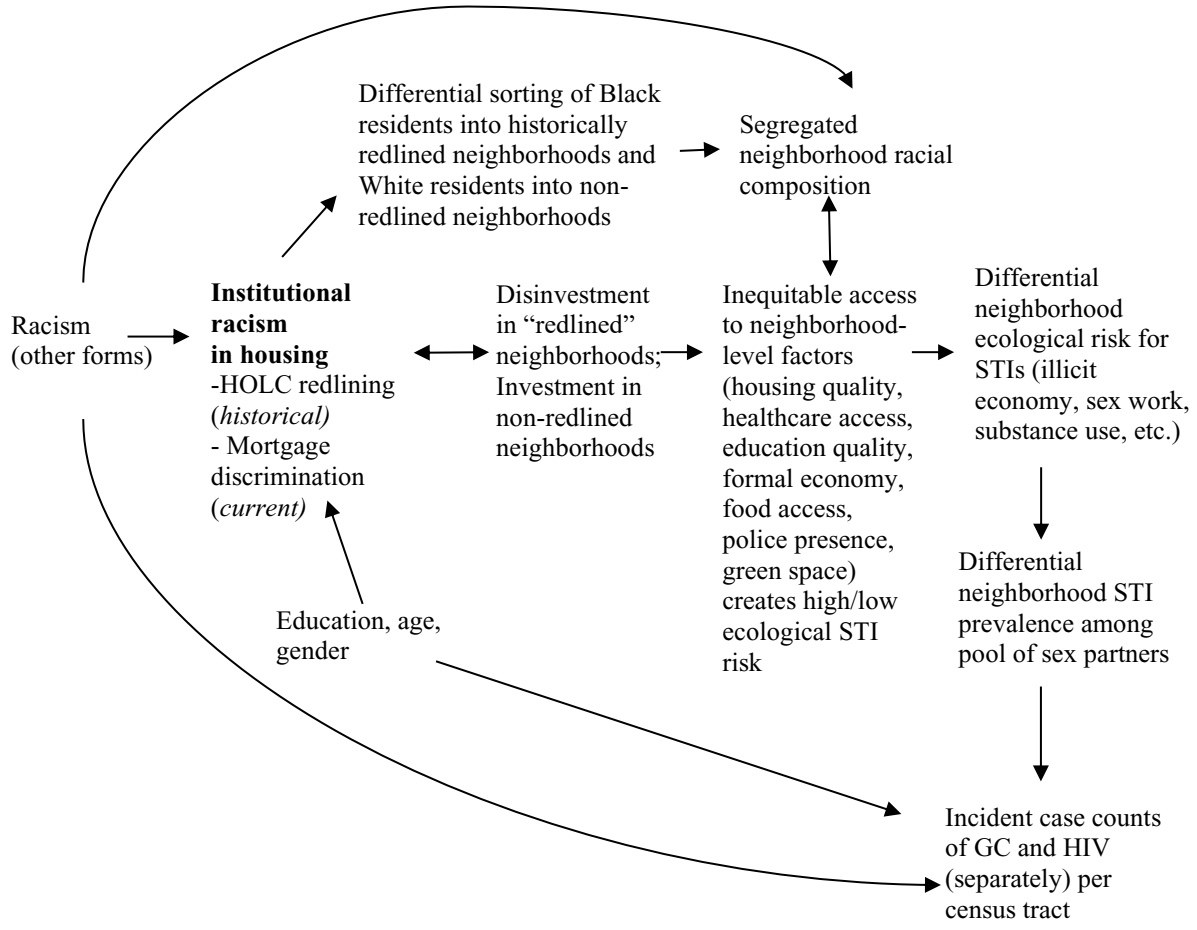


Table 1. Mortgage discrimination index: Odds of Black vs. White applicant mortgage loan denial across 196 census tracts in Baltimore city using HMDA data from 2016-2018.*

	Black applicants		**White applicants**		**Adjusted OR**	
Year	n	Percent denied	n	Percent accepted	Mean (95% CI)	Range
2016	3,363	44.3 (1489/3363)	4,991	17.1 (855/4991)	3.09 (1.32, 8.11)	[1.04, 6.42]
2017	3,184	34.2 (1089/3184)	4,028	12.8 (515/4028)	2.89 (1.27, 7.27)	[1.36, 6.45]
2018	4,429	40.0 (1769/4429)	4,533	18.7 (848/4533)	2.20 (1.17, 4.15)	[1.16, 3.37]
All	10,976	39.6 (4347/10976)	13,552	16.4 (2218/13552)	2.59 (1.34, 5.14)	[0.94, 6.24]

*Adjusted for loan amount, applicant income, and applicant sex.

Table 2. Selected census-tract level characteristics by quartiles of increasing mortgage discrimination index (2016-2018)*

Characteristic	**Mean ± SD**	**Q1 index**	**Q2 index**	**Q3 index**	**Q4 index**
Census Tracts	n=196	n=49	n=47	n=46	n=47
GC case count	56.46 ± 36.02	68.08 ± 30.94	66.60 ± 35.15	61.00 ± 36.46	28.60 ± 27.17
HIV case count	3.66 ± 2.80	4.02 ± 2.57	3.94 ± 2.44	3.74 ± 2.39	2.43 ± 3.03
Median age	35.96 ± 6.21	36.50 ± 6.39	36.85 ± 6.07	36.25 ± 6.61	34.68 ± 5.7
Percent female	53.21% ± 4.33%	53.87% ± 4.41%	53.73% ± 4.38%	54.00% ± 3.64%	50.92% ± 4.06%
Percent < HS education	16.65% ± 9.33%	19.14% ± 8.43%	19.27% ± 8.86%	19.10% ± 9.43%	9.96% ± 7.37%

*Quartiles of mortgage discrimination index: lowest quartile (Q1) indicates lowest odds of mortgage discrimination, while highest quartile (Q1) indicates highest odds of racial discrimination.

Table 3. Census-tract level characteristics by low vs high case counts of GC diagnoses, n=196 census tracts*

Characteristic	Low GC Count (Below/Equal to Median)*, n=99 (Mean ± SD)	High GC Count (Above Median)*, n=97 (Mean ± SD)	P-value
Mortgage discrimination index	2.82 ± 0.80	2.37 ± 0.72	<0.01
Median age	36.34 ± 6.48	35.57 ± 5.92	0.39
Percent female	52.46% ± 4.25%	53.97% ± 4.29%	0.01
Percent < high school education	13.14% ± 9.37%	20.23% ± 7.84%	<0.01

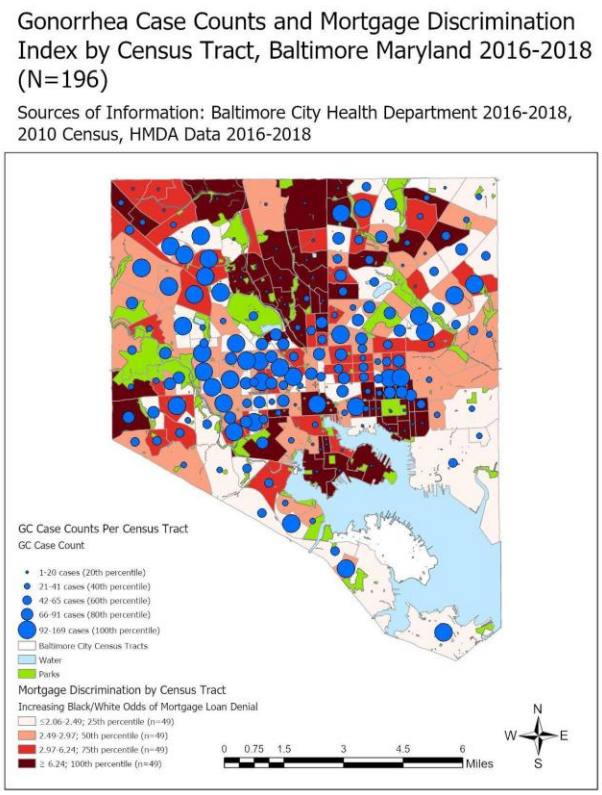
*Low GC count: less than or equal to median GC count (53 cases). High GC count: greater than median GC count (53 cases)

Table 4. Census-tract level characteristics by low vs high case counts of HIV diagnoses, n=196 census tracts*

Characteristic	Low HIV Count (Below/Equal to Median)*, n=108 (Mean ± SD)	High HIV Count (Above Median)*, n=88 (Mean ± SD)	P-value
Mortgage discrimination index	2.74 ± 0.78	2.42 ± 0.78	<0.01
Median age	36.12 ± 6.51	35.763 ± 5.85	0.69
Percent female	52.89% ± 4.51%	53.60% ± 4.09%	0.25
Percent < HS education	14.38% ± 9.19%	19.45% ± 8.76%	<0.01

*Low HIV case count: less than or equal to median HIV count (3 cases). High HIV case count: higher than median HIV count (3 cases).

Figure 2. Distribution of mortgage discrimination index, GC case counts, and HIV case counts by Baltimore City Census Tracts



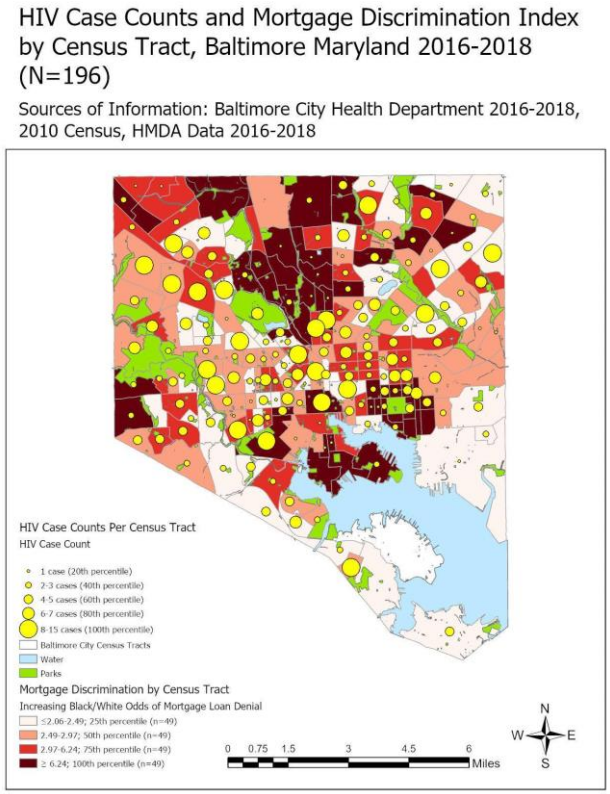


Table 5. Sensitivity analysis: IRR (95% CI) for association between mortgage discrimination index and STI outcomes (n=196 CTs)

	GC	**HIV**
Poisson	0.47 (0.46, 0.49)*	0.61 (0.55, 0.67)*
AIC, BIC	*5250.26, 5256.82*	*993.86, 1000.42*
Zero-inflated Poisson	0.48 (0.46, 0.49)	0.67 (0.61, 0.74)*
AIC, BIC	*5153.97, 5167.08*	*849.42, 862.53*
Negative binomial	0.73 (0.65, 0.82)*	0.91 (0.80, 1.03)
AIC, BIC	*1925.39, 1935.23*	*910.73, 920.57*
Zero-inflated NB	0.73 (0.65, 0.82)*	0.98 (0.87, 1.09)
AIC, BIC	*1915.82, 1932.21*	*808.75, 825.14*

* p<0.01, ** p<0.05

Table 6. Unadjusted and adjusted associations between census-tract level mortgage discrimination (2016-2018), demographic characteristics (2012-2017), and HIV & GC case counts (2016-2018), Baltimore City, Maryland (N=196 census tracts)

Characteristic	**GC Count Unadjusted IRR** (95% CI)	**GC Count Adjusted IRR†** (95% CI)	**HIV Count Unadjusted IRR** (95% CI)	**HIV Count Adjusted IRR†** (95% CI)
Mortgage discrimination index***	0.73 (0.65, 0.82)**	0.83 (0.74, 0.93)**	0.98 (0.87,1.09)	1.02 (0.90, 1.16)
Median age	1.00 (0.99, 1.02)	1.01 (0.99, 1.02)	1.01 (0.99, 1.02)	1.00 (0.99, 1.02)
Percent female	21.70 (2.02, 233.32)*	3.61 (0.25, 31.87)	1.29 (0.14, 11.60)	1.36 (0.14, 13.54)
Less than high school education	66.89 (21.40, 209.10)**	37.17 (12.09, 114.25)**	2.97 (1.06, 8.28)*	3.08 (1.05, 9.02)*

* p<0.05, ** p<0.01, **Continuously modeled.

†Adjusted zero-inflated negative binomial model included median age, percent female, and percent with less than high school education.

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Vita

EDUCATION

Master of Science, Infectious Disease Epidemiology (Aug 2020), Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

Bachelor of Science, Biology (May 2016), Case Western Reserve University, Cleveland, OH

RESEARCH EXPERIENCE

Graduate Research Assistant, Johns Hopkins School of Medicine, Baltimore, MD; May 2019-August 2020. Analyzed relationship between neighborhood factors and STI case counts.

Graduate Research Assistant, Universidad de los Andes, Bogotá DC, Colombia; Andres Vecino-Ortiz, MD PhD; July-August 2019. Studied gun control effectiveness through interviews, literature review, and media analysis.

Graduate Research Assistant, Epidemiology Department, Johns Hopkins School of Public Health; John Jackson, ScD; January-May 2019. Conducted literature review of segregation and cardiovascular healthcare seeking.

Research Intern, NYC Department of Health, New York, NY; Bisrat Abraham, MD MPH; February- July 2018. Analyzed results of HIV clinic survey.

Research Assistant, Spatial Epidemiology Lab, NYU School of Medicine, New York, NY; Dustin Duncan, ScD; November 2017-July 2018. Conducted literature reviews, helped edit grants, and performed qualitative analysis on racial/ethnic and sexual/gender health disparities.

Clinical Research Coordinator, Cleveland Clinic, Cleveland, OH; November 2016-November 2017. Managed the data and regulatory coordination of 13 clinical oncology trials.

PUBLICATIONS

Dubin, S., Reisner, S., Schrimshaw, S., Radix, A., Khan, A., Harry-Hernandez, S., **Zweig**, **S.A.**, Timmins, L., Duncan, D. T. Public Restrooms in Neighborhoods and Public Spaces: A Qualitative Study of Transgender and Non-Binary Adults in New York City. In review.

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